

Robotic Telepresence: Past, Present, and Future

Kevin K. Chung, MD,* Kurt W. Grathwohl, MD,* Ron K. Poropatich, MD,† Steven E. Wolf, MD,*
and John B. Holcomb, MD*

THE SCOPE of telemedicine defined as “the use of telecommunications to allow caregivers to interact with patients and/or other caregivers operating at remote locations” is very broad.¹ For example, the Army’s current telemedicine program, as described by Poropatich et al,² encompasses a wide breadth of various forms of information that is transmitted and shared for the purpose of patient care, education, and other communication, from the transmission of dermatologic or radiologic images to real-time video telemonitoring support in the intensive care unit. For the purposes of this review, the discussion is limited to telemedicine that uses real-time video telecommunications capabilities.

Telemedicine for real-time, face-to-face clinical consultation was first described in 1977 by Grundy et al.³ In their 6-month experience using “a 2-way audiovisual link” between a small private hospital and a large university medical center, they reported the following: (1) regular consultation in critical care can be provided, (2) telemedicine can be made acceptable to users and providers, (3) the audiovisual link is superior to the telephone, and (4) telemedicine can favorably influence the quality of care in a critical care unit. In 1982, Grundy et al⁴ published a follow-up study evaluating 1,548 telemedicine “visits” by intensivists for 395 patients in another hospital with no onsite intensivist coverage. This intermittent, as-needed, remote teleconsultative service was described as having a greater clinical and educational impact than the telephone but was not ready for widespread implementation partly because of the expense.

Since these pioneering reports, remote telepresence via stationary, multicamera monitoring systems or manually transported platforms that provide videoconferencing capabilities has become widely available and reported in the literature. One telemedicine application designed for the intensive care unit is the eICU (VISICU, Baltimore, MD). In this model, intensivists from a dedicated facility (the eICU) centrally supervise and monitor patients in multiple intensive care unit (ICU) locations simultaneously via real-time remote monitoring, access to electronic medical records, and videoconferencing.⁵ In a 16-week study, this remote intensivist monitoring program reduced severity-adjusted hospital mortality for patients in a 10-bed surgical ICU by 30% while simultaneously decreasing ICU length of stay and costs.⁶ A more recent analysis of the eICU technology in a large tertiary care hospital found that in-hospital mortality decreased from 12.9% (before eICU implementation) to 9.4% (after eICU implementation).⁷

Telemedicine applications appear to be quite successful in supporting emergency department providers in the care of trauma and stroke patients. In most cases, videoconference-capable workstations are mounted on manually mobile carts for proper positioning in various areas of interest. Rogers et al⁸ reported improvement in early trauma care in emergency departments at satellite community hospitals when remotely directed by trauma surgeons located at a level I trauma center.⁹ The application of telemedicine capability in centers lacking in-house neurology consultative services has resulted in scores

of patients receiving brain-saving thrombolytic therapy in a timely manner.¹⁰⁻¹⁴

ROBOTIC TELEPRESENCE

Remote presence is a wireless mobile robotic telemedicine technology that consists of a desktop or laptop control station and a robot (RP-7; InTouch Health, Santa Barbara, CA) (Figs 1 and 2). A 2-way, audio-video communications capability is made possible with the custom integration of digital cameras, audio microphones, amplification circuitry, and custom software. When the RP-7’s pan-tilt-zoom head and omnidirectional (holonomic) mobility base are combined with high-speed broadband (300-600 kbp) internet capability, a physician can now project himself/herself to another location to move around, see, hear, talk, and interact as though he/she was actually there. The result is a “virtually there” audiovisual communication between the physician specialist and physician or nurse attending to the needs of the patient. Through the control station, the physician specialist can also monitor the patient via the robot from any remote location with wireless or cable internet access. Remote presence effectively presents to the physician specialist any remote patient in the environment (ICU, ward, and emergency department) to develop the patient care plan, effect change in care plan, and/or oversee the patient-care plan.

Various applications of Robotic Telepresence (RTP) were recently reported in the literature. Ellison et al¹⁵ evaluated the impact of using RTP for postoperative “telerounds.” In 85 patients who had undergone a urologic procedure, standard once-daily attending bedside rounds were compared with once-daily rounds with an additional afternoon RTP round and daily bedside rounds with 1 RTP substitution visit. The authors concluded that RTP was associated with increased patient satisfaction because of better attending physician availability and improved communication of medical information.

Remote surgical proctoring was evaluated by Smith and Skandalakis.¹⁶ Surgeons used RTP to remotely supervise and direct medical students during cadaver dissection. Authors noted that the surgeons’ ability to effectively move around the environment provided both student and proctor the feeling of true presence, providing an advantage over prior multiple fixed-camera video teleconferencing capabilities.

From the *United States Army Institute of Surgical Research, Fort Sam Houston, TX; and †United States Army Medical Research and Materiel Command, Fort Detrick, MD.

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Address reprint requests to Kevin K. Chung, MD, US Army Institute of Surgical Research, 3400 Rawley E. Chambers Ave, San Antonio, TX 78234-6315. E-mail: kevin.chung@amedd.army.mil

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Fig 1. The RP-7 interacting with the ICU nurse. (Color version of figure is available online.)

Perhaps the greatest impact of RTP was reported by Vespa et al.¹⁷⁻¹⁹ In their 1-year prospective observational study designed to evaluate the impact of RTP in a neurosurgical ICU, the authors noted that RTP resulted in significantly shorter attending response times to the bedside for unstable patients. Even more striking was their resulting decrease in ICU length of stay and ICU cost savings of \$1.1 million attributed to the use of RTP.

RTP has been used at the authors' institution in both the surgical ICU and burn ICU. As an academic center, resident



Fig 3. The physician assessing the patient and ventilator settings via the RP-7. (Color version of figure is available online.)



Fig 2. Laptop workstation. The physician assessing the bedside ICU vitals monitor via the RP-7. (Color version of figure is available online.)



Fig 4. The physician making bedside rounds and interacting with the ICU nurse via the RP-7. (Color version of figure is available online.)

and physician assistant house staff members provide in-house call coverage. Via RTP, the critical care staff providers who are on pager call from home are able to perform nighttime rounds; make ventilator, fluid, and medication adjustments; provide patient updates to family members; and supervise procedures (Figs 3 and 4). On 1 occasion, a code was conducted by the critical care staff via RTP when a patient went into cardiac

arrest during a routine afternoon visit. Both physician and nursing staff, some of whom were initially skeptical, often point to this event as the one RTP interaction that resulted in complete ICU "buy-in." Its overall utility is currently being evaluated in a year-long prospective observational study. After 6 months, the overall impression of RTP technology has been largely positive based on questionnaires completed by the physicians, nurses, and family members.

The RTP is specifically designed to easily enable movement from one bed to another in an open ICU or emergency room bay. Navigation through doors and elevators requires an escort, and travel across long distances is not practical. Thus, for practical use of the robot, on-call providers prestation the robot in the area it will most likely be used. Because multiple same-network robot access is possible in a hospital setting, it would be preferable to have multiple robots strategically located at high-traffic areas. A provider could sequentially access multiple robots and move from one robot on a given floor to another all from a fixed location. In fact, it is even feasible to access multiple same-network robots in different locations thousands of miles apart as long as broadband wireless access exists at each location. Given that the authors' institution is limited to 1 robot, the RTP has been used primarily in 1 ICU.

TELEMEDICINE IN ANESTHESIA

The reported use of telemedicine specifically for anesthesia-related purposes is limited to case reports of remote consultation for complex patients in Ecuador and India. Satellite with low-bandwidth connection allowed anesthesiologists from Richmond, VA, to assist in preoperative patient evaluations, observe endotracheal intubations, and monitor vital signs data, including capnography and arterial wave blood pressure readings to provide consultation for patients being managed in Ecuador.^{20,21} More recently, an integrated services digital network line allowed providers at Children's Hospital of Philadelphia to provide both perioperative teaching and live consultation to physicians providing anesthetic support for pediatric liver transplantation.²² A prospective pilot study tested the feasibility of providing preadmission evaluation in 10 patients from distant areas of Ontario, Canada. The consultation was adequate for the anesthesia providers and was well accepted by patients. Additionally, there was significant cost and time savings for travel.²³

Anesthesiologists at Vanderbilt University use a novel telemedicine system to observe operations and vital signs in multiple operating rooms simultaneously.²⁴ The anesthesiologist provides consultation for certified registered nurse anesthetists and anesthesiology residents.²⁴ This technology allows the anesthesiologist to perform multiple tasks that may prove to improve operating room efficiency, speed operating room turnover, improve patient flow, and increase patient safety.²⁴ The anesthesiologist is instantly alerted for critical changes to any of the patients for whom he/she is responsible.²⁴ Similar telemedicine concepts are being used in the development of the operating room of the future to improve the delivery and safety of anesthesia.

The combination of telemedicine and robotics, under the

RTP platform, has never been used in the delivery of anesthesia care. Its potential use in various clinical practice settings is easy to envision. One anesthesiologist, for example, can potentially supervise multiple certified registered nurse anesthetist or resident cases. One robot strategically located between 2 and 4 rooms could easily be navigated to "cover" those rooms. Another robot could be stationed in the postanesthesia care unit, which would enable a provider to be instantly available to answer questions or to "check up" on postoperative patients. This could potentially improve availability, efficiency, continuity, and efficacy of care because of the timeliness of any intervention. With multiple robots, the supervisory capacity of 1 anesthesia provider could multiply by 2- to 3-fold. In areas in which subspecialty anesthesia provider shortages exist, RTP is certainly appealing. Well-done cost analyses are needed to establish cost-effectiveness of this type of technology in this setting as well as those described previously.

FUTURE OUTLOOK

At the moment, RTP applications are limited by their wireless broadband requirements. Thus, "deploying" a robot to a remote location to provide instant advanced telecommunications capability may not be realistic. Thus, its potential utility in the setting of natural disaster response or chemical, biological, and nuclear attack is questionable. The possibility of broadening the use of RTP technology within the Department of Defense is currently being investigated. The main limitation is the bandwidth available in certain areas of interest.

Depending on the medical specialty, shortages in staffing in most hospitals already exist or are projected to exist. As technology continues to enable faster communications over longer distances with far-reaching wireless capability, it will become easier and easier to project "medical expertise" to areas in which these shortages exist. RTP has tremendous potential to help provide that relief. Currently, Medicare already provides reimbursement for services provided via RTP. However, reimbursement is limited to "telemedicine" care delivered in a rural health professional-shortage area or counties not in a metropolitan statistical area.²⁵ As the scope of telemedicine grows beyond these areas, interwoven as merely a vital limb of modern clinical practice, reimbursement laws will need revision. Clinicians can easily envision using RTP technology allowing bidirectional communication among medical providers throughout established networks. These networks can be used for data sharing, educational conferences, quality improvement projects, and complex patient management. Additionally, the idea of video teleconferencing is made more widely available to providers of all different levels. RTP also allows several dimensions of medical care that were not previously available. For example, providers can take pictures or video of patients, physical findings, wounds, or procedures that can be permanently documented in the medical record and used for comparison or as a matter of record. Once clinical value can be shown and proper reimbursement for clinical care rendered is possible, the conditions will be primed for the field of telemedicine and specifically RTP to become widespread.

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